National Aeronautics and Space Administration

Power to Explore

RADIOISOTOPE POWER SYSTEMS

VENUS
- Galileo (GPHS-RTG)
- Cassini (GPHS-RTG)

SUN
- Ulysses (GPHS-RTG)

SATURN
- Pioneer 11 (SNAP-19 RTG)
- Voyager 1 (MHW-RTG)
- Voyager 2 (MHW-RTG)
- Cassini (GPHS-RTG)

EARTH
- Nimbus 3 (SNAP-19B RTG)
- Voyager 1 (MHW-RTG)
- Galileo (GPHS-RTG)
- Cassini (GPHS-RTG)

TITAN
- Voyager 1 (MHW-RTG)
- Cassini (GPHS-RTG)
- *Dragonfly (MMRTG)
  *Planned for 2027

MOON
- ESAP/Apollo 11 (RHU)
- ALSEP/Apollo 12 (SNAP-27 RTG)
- ALSEP/Apollo 14–17 (SNAP-27 RTG)

URANUS
- Voyager 2 (MHW-RTG)

MARS
- Viking 1 (SNAP-19 RTG)
- Viking 2 (SNAP-19 RTG)
- Sojourner/Pathfinder (RHU)
- Spirit/MER (RHU)
- Opportunity/MER (RHU)
- Curiosity/MSL (MMRTG)
- Perseverance/ Mars 2020 (MMRTG)

NEPTUNE
- Voyager 2 (MHW-RTG)

TRITON
- Voyager 2 (MHW-RTG)

KUIPER BELT AND BEYOND
- Pioneer 10 (SNAP-19 RTG)
- Pioneer 11 (SNAP-19 RTG)
- Voyager 1 (MHW-RTG)
- Voyager 2 (MHW-RTG)
- New Horizons (GPHS-RTG)

JUPITER
- Pioneer 10 (SNAP-19 RTG)
- Pioneer 11 (SNAP-19 RTG)
- Ulysses (GPHS-RTG)
- Galileo (GPHS-RTG)
- Cassini (GPHS-RTG)
- Voyager 1 (MHW-RTG)
- Voyager 2 (MHW-RTG)
- New Horizons (GPHS-RTG)

PLUTO SYSTEM
- New Horizons (GPHS-RTG)

Types of Missions
Flyby · Orbit · Land · Rove

PROUD PAST—STRONG FUTURE

www.nasa.gov

Radioisotope Power Systems

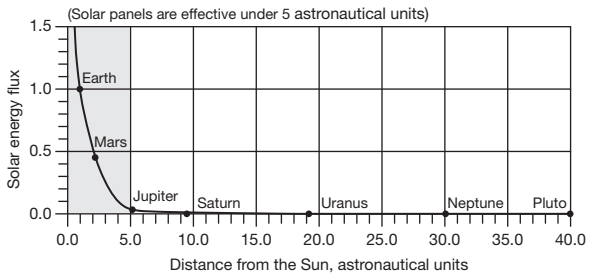
For more than six decades, radioisotope power systems (RPS) have played a critical role in the exploration of space, enabling missions of scientific discovery to destinations across the solar system. RPS-powered spacecraft have explored every planet in our solar system from Venus outward—including the weather systems of Earth—and the polar regions of the Sun, as well as Pluto and the Kuiper Belt. Several of these hardy robotic emissaries continue to probe the most distant fringes of our solar system, with Voyager 1 and 2 both having broken through to reach the eerie, empty vacuum of true interstellar space.

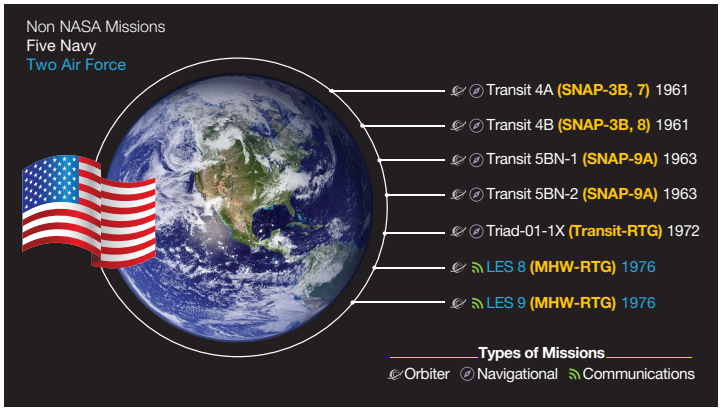
Power to Explore

Power is the one thing a spacecraft cannot do without. Without the technology to reliably power space missions, our knowledge of the solar system would be only a fraction of what it is today. There are currently only two practical options for providing a long-term source of electrical power for exploring space: the light of the sun or heat from a nuclear source such as a radioisotope.

Solar power is an excellent way to generate electricity for most Earth-orbiting spacecraft, and for other missions that offer sufficient sunlight and natural heat. However, many potential NASA missions given a high priority by the scientific community would visit some of the harshest, darkest, coldest locations in the solar system, and these missions could be impossible or extremely limited in capabilities without the use of nuclear power.

Choosing a Power System Based on Distance



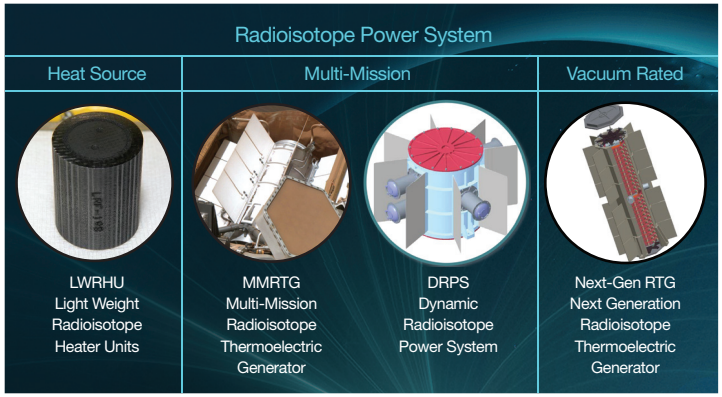


Radioisotope power is a type of nuclear energy technology that uses heat to produce electric power to operate spacecraft systems and science instruments. That heat is produced by the natural radioactive decay of plutonium dioxide.

Choosing between solar and nuclear power for a space mission has everything to do with where a spacecraft needs to operate and what the mission must accomplish when it gets there. Radioisotope power is used only when it will enable or significantly enhance the ability of a mission to meet its science goals.

Critical Technology for Exploration

RPS offer several important benefits. They are compact, rugged and provide reliable power in harsh environments where solar arrays are not practical. The ability to utilize radioisotope power is especially important for missions to the outer solar system, as the size of solar arrays required at such distances is impractically large with currently available technology.



RPS offer the key advantage of operating continuously over long-duration space missions, independent of changes in sunlight, temperature, charged particle radiation, or surface conditions like thick clouds or dust. In addition, some of the excess heat produced by some radioisotope power systems can be used to enable spacecraft instruments and on-board systems to operate effectively in extremely cold environments.

A 60-Year Legacy

Radioisotope power systems are not a new part of the U.S. space program. They have made historic contributions to our exploration of space for more than 60 years. The U.S. has flown 31 missions with radioisotope power systems over the past six decades with an outstanding safety and reliability record.

An Evolving Technology

NASA's solar system exploration missions are prioritized by a vigorous strategic planning process that incorporates the best ideas from internal and external scientific experts. These experts have consistently identified RPS as a fundamentally important technology. In the future, radioisotope power systems could continue to support missions to some of the most extreme environments in the solar system: probing the secrets of Jupiter's ocean moon Europa, Saturn's moon Titan, sampling a comet, or touring the rings and moons of the ice giant planet Uranus.

Today, NASA is planning for a return of astronauts to the Moon. Part of this exploration could include a demonstration of the first dynamic RPS in space—this type of system uses a piston or other movable element to generate electricity about three times as efficiently as the radioisotope thermoelectric generators that have been flown to date.

For more information visit http://rps.nasa.gov

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